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(54) Title: **BINDER FOR MINERAL WOOL PRODUCTS**

(57) Abstract: Process for providing a binder for mineral wool products, said process comprising the steps of: mixing together under reactive conditions a carboxylic acid with an alkanolamine, whereby optionally these are firstly mixed to provide a resin which resin is subsequently reacted with a separate carboxylic acid group containing polymer.

## BINDER FOR MINERAL WOOL PRODUCTS

The invention relates to a process for providing a binder for mineral fibers, i.e. man made vitreous fibers, for example glass, slag or stone wool, a binder obtainable via such a process, and a mineral wool  
5 product comprising such a binder.

Mineral wool products generally comprise mineral fibers bonded together by a cured thermoset polymeric material. One or more streams of molten glass, slag or stone are drawn into fibers and blown into a  
10 forming chamber where they are deposited as a web on to a travelling conveyer. The fibers, while airborne in the forming chamber and while still hot are sprayed with a binder. The coated fibrous web is then transported from the chamber to a curing oven where heated air is blown  
15 through the mat to cure the binder and rigidly bond the mineral wool fibers together.

Phenol-formaldehyde binders are widely used in the mineral wool industry since they have a low viscosity in the uncured state, yet still form a rigid thermoset  
20 polymeric matrix for the mineral fibers when cured.

However the use of phenol formaldehyde binders is becoming increasingly undesirable due to the use and release of environmentally unfavourable chemicals during the process.

25 The use of  $\beta$ -hydroxyalkylamides to cure polycarboxy polymers such as polyacrylic acid in order to provide a binder is known.

A problem with polyacrylics cured by  $\beta$ -hydroxyalkylamides is that mineral wool products bound  
30 with such a resin normally exhibit good mechanical properties before ageing, but after exposure to high humidities and increased temperatures, for example above

40 degrees centigrade, the mechanical properties are drastically reduced.

There is therefore a desire to develop a binder which improves on the known binders.

5 An object of the present invention is to provide an alternative binder aimed at overcoming one or more of these problems.

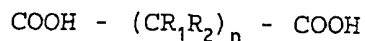
According to a first aspect of the present invention, there is provided a process for providing a  
10 binder for mineral wool products said process comprising the steps of:

- mixing together under reactive conditions a carboxylic acid with an alkanolamine.

The resulting binder when utilized for a  
15 mineral wool product, provides the mineral wool product with desirable mechanical properties after ageing, subjection to tear strain and exposure to high humidities and increased temperatures.

The carboxylic acid and the alkanolamine are  
20 preferably firstly mixed together under reactive conditions to provide a resin, which resin optionally is subsequently mixed with a separate carboxylic acid group containing polymer to form a binder.

The carboxylic acid is preferably a di-, tri-,  
25 or tetra carboxylic acid having a molecular weight of about 1000 or less, preferably about 500 or less, and most preferably about 200 or less, most preferably a di-carboxylic acid having the general formula:



30 wherein  $n \geq 2$  and preferably  $n \geq 4$ , and wherein  $R_1$  and  $R_2$  are independently selected from H or a lower alkyl group, preferably a methyl or ethyl group.

The carboxylic acid is preferably selected from the group consisting essentially of: adipic acid, citric  
35 acid, trimellitic acid, sebacic acid, azelaic acid, and succinic acid and is most preferably adipic acid.

The alkanolamine is preferably selected from the group comprising di, and tri-alkanolamines, and can

be a secondary beta-hydroxy alkylamine, preferably an N-substituted alkanolamine selected from the group consisting essentially of, di-ethanolamine, 1-(m)ethyldiethanolamine, n-butyldiethanolamine, 3-amino-1,2-propanediol, 2-amino-1,3,-propanediol, tris(hydroxymethyl)aminomethane, most preferably being diethanolamine.

The mole ratio of the carboxylic acid to the alkanolamine in the binder preferably lies in the range of 0.1-1:1-0.1 and the weight percentage of the carboxylic acid group containing polymer in the binder can lie in the range of 0.5-50, for example 10-40, preferably 15-30, most preferably about 20.

The alkanolamine is preferably firstly heated to around 60°C, whereafter the carboxylic acid is added and the temperature of this mixture is subsequently raised to about at least 90°C, preferably a temperature lying in the range of about 95-200, for example about 120-150°C.

The carboxylic acid group containing polymer preferably has a molecular weight lying in the ranges of 1000-300000, for example 1000-250000, preferably 1000-200000 most preferably having a molecular weights of around 60000, around 100000 and around 190000.

The carboxylic acid group containing polymer preferably comprises one or more of the following: polyacrylic acid, polymethacrylic acid, polymaleic acid and/or co-polymers thereof, preferably being selected from one or more of the following:

- HF-05A, Rohm & Haas,
- Acusole 190, Rohm & Haas,
- Acumer 1510, Rohm & Haas,
- 41.600-2, from the Aldrich Chemical Company Inc.

One or more of the following additives can be added to the binder:

- a coupling agent, for example an aminosilane, preferably gamma-aminopropyltriethoxysilane,

- a polymerisation accelerator, a curing accelerator and optionally further standard mineral wool binder additives.

In order to improve the water solubility of the resin a base might be added till a pH up to 7. The base is preferably mixed with a polyacrylic acid and added to the resin reaction mixture after the resin reaction is preferably stopped by water addition. Accordingly, the base can first be added after the resin is prepared.

10 Suitable bases include  $\text{NH}_3$ , DEA, TEA.

Further characteristics are referred to in claims 18-23.

In order to improve the ageing constancy properties a silane may be added. The silane usually but is not restricted to be added during the binder preparation or directly (separately) at the line. The amount would normally be in the range from 0,1% to 5% (0,2%-3%). Preferred amount is approximately 1%.

According to further aspects of the present invention there is provided a binder obtainable according to this process, a process for providing a mineral wool product, a mineral wool product and the use of a reaction mixture of an alkanolamine and a carboxylic acid, optionally mixed with a carboxylic acid group containing polymer, as a binder for a mineral wool product.

20

The invention will now be further illustrated by way of the following examples and results.

Example 1

158 g diethanolamine was placed in a 1-liter glass reactor provided with a double jacket and an agitator. Temperature of the diethanolamine was raised to 60°C whereafter 99 g adipic acid was added slowly. The temperature was raised to 95°C. After a reaction time of 1 hour at about 95°C the reaction was stopped by the addition of 200 g water. The reaction product was a clear, colourless, low viscous liquid, dilutable with water.

Example 2

158 g diethanolamine was placed in a 1-liter glass reactor provided with a double jacket and an agitator. Temperature of the diethanolamine was raised to 60°C whereafter 175 g adipic acid was added slowly. The temperature was raised to 95°C. After a reaction time of 1 hour at about 95°C the reaction was stopped by the addition of 200 g water. The reaction product was a clear, colourless, low viscous liquid, dilutable with water.

Example 3

67,2 g triethanolamine was mixed with 33,0 g adipic acid at room temperature. After the solution had turned clear 60 ml temperate water was added. The mixture was a clear, colourless, low viscous liquid, dilutable in water.

Example 4-6

Resins were made using the same procedure as in example 1. The following amounts of chemicals were used:

Table 1

	Alkanolamine	Polycarboxylic acid	Water
Example 4	158 g Diethanolamine	243 g Azelaic Acid	200 ml
5 Example 5	158 g Diethanolamine	141 g Sebacic Acid	200 ml
Example 6	158 g Diethanolamine	89 g Succinic Acid	200 ml

Example 7

158 g diethanolamine was placed in a 1-liter  
10 glass reactor provided with a double jacket and an  
agitator. The temperature of the diethanolamine was  
raised to 60°C whereafter 99 g adipic acid was slowly  
added. The temperature was subsequently raised to about  
130°C, the temperature being maintained between 128 and  
15 135°C. After a reaction time of 3 hours the reaction was  
stopped by the addition of water.

All the produced reaction products in examples  
4-7 were clear colourless low viscous liquids, dilutable  
20 in water.

Example 8

Preparation and testing of selected binder  
samples to evaluate the binding strength towards shots  
25 with mineral fibre composition (Grit bar test). As shots  
are considered unfiberized fiber material with identical  
composition as the fibers.

Shots with size between 0,25 and 0,5 mm  
diameter were used to make bars with dimensions 140 mm x  
30 25 mm x 10 mm.

A binder solution was prepared comprising 80%  
of the resins from examples 1-7 mixed at room temperature  
with 20% of a commercial polyacrylic resin.

As polyacrylic acids were used the commercial  
35 types from Rohm & Haas: HF-05A, Acusole 190 and Acumer

1510, and a polyacrylic acid with an average mole weight of 250.000 (Aldrich Chemical Company Inc. 41.600-2).

For making the bars 90 ml binder solution with 15 % solids content and 0,2 % silane coupling agent of 5 binder solids were mixed with 450 g shots.

The coupling agent was gamma-aminopropyltriethoxysilane.

Out of the 450 g shots mixed with binder solution, 8 bars were made which were cured 2 hours at 10 200°C in an incubator.

Four of the bars were broken directly (dry strength), the other 4 are placed 3 hours in 80°C water before they are broken (wet strength).

The binding strength was determined by breaking 15 the bars in a measuring device, where the clamping length is 100 mm and the velocity of the compressing beam was 10 mm/min. Using the clamping length, width and thickness of the bars, the bending strength was determined in N/mm<sup>2</sup>.

For comparison a commercial product Primid 20 XL-552 from EMS Chemie AG was used. Primid XL-552 is the reaction product of a dimethylester of adipic acid and diethanolamine, whereby the inventors have shown that 100% Primid is not curable since only free OH-groups are present which do not cross-link. A mixture of 80% primid 25 and 20% PAA yielded a very fast curing time (45s (HF-05) and 20s (Mw 250,000) at 200°C) but the products have no remaining strength after ageing. The results are shown in table 2.



Table 2

	Resin	Polyacrylic acid	Unaged strength N/mm <sup>2</sup>	Aged strength N/mm <sup>2</sup>	Remaining strength (aged/ unaged)
5	80% Example 1	20% HF05	9.6	2.0	21%
	80% Example 1	20% PAA MW 250000	9.7	4.6	47%
	80% Example 2	20% HF05	10.0	5.3	53%
10	80% Example 2	20% PAA MW 250000	6.9	4.5	66%
	80% Example 3	20% HF05	7.7	6.2	81%
15	comparison example 80% Primid XL-552	20% HF05	3.6	0	0%
	60% Example 2	40% HF05	8.1	4.0	49%
20	20% Example 2	80% HF05	8.5	1.5	18%
	20% Example 2	80% PAA, Mw 250,000	4.5	4.0	89%
25	80% Example 4	20% PAA MW 2,000	6.6	3.1	47%
	80% Example 5	20% PAA Mw 2,000	8.0	4.7	59%
	80% Example 6	20% PAA Mw 250,000	7.5	0.4	5%
30	80% Example 7	20% Acusol 190	8.0	2.4	30%
	80% Example 7	20% Acumer 1510	9.2	3.2	35%

35

Measurement of curing times for selected examples

A few droplets of the binder to be examined were placed on a microscope cover glass. The glass was dried in a heating cupboard at 90 °C for 45 min.

After drying the cover glass was placed on a heating stage at 250°C and while stirred with a piece of metal wire (straightened paper-clips) the time was measured until the binder was cured.

5 The results are shown in table 3.

Table 3: Results

Resin	Polyacrylic acid	Curing time 200 °C	Curing time 250 °C
10 80% Example 1	20% HF05	-	90 s
80% Example 1	20% PAA, Mw 250,000	-	25 s
80% Example 2	20% HF05	140-160 s	45 s
80% Example 2	20% PAA, Mw 250,000	-	25 s
80% Example 4	20% HF05	173 s	43 s
15 80% Example 5	20% HF05	285 s	50 s
80% Example 7	20% Acusol 190	35 s	-
80% Example 7	20% Acumer 1510	30 s	-

20 As polyacrylic acids were used the commercial types from Rohm & Haas: HF-05A, Acusole 190 and Acumer1510, and two pure polyacrylic acids with average mole weights of 2000 and 250,000 respectively (Aldrich Chemical Company Inc. 32,366-7 and 41,600-2)

25

#### Example 9

20.8 kg Diethanolamine were transferred to a 80 liter steel reactor provided with an agitator and a heating/cooling jacket and heated to 60°C. 23.0 kg Adipic

Acid were added to the reactor in 5 portions and the temperature raised to a reaction temperature of 95°C. After reaction for 1 hour 26.3 kg temperate water were added, whereafter the resin was cooled to room  
5 temperature.

The resulting resin was a clear colourless low viscous liquid dilutable with water.

At room temperature 80% of the above resin was mixed with 20% of a commercial Polyacrylic resin from  
10 Rohm & Haas: HF-05.

The produced resin was after mixing with water and addition of 0.2% of a silane coupling agent used as a binder in a production trial on a standard stonewool line. The product produced was a standard slab with a  
15 density of 100 kg/m<sup>3</sup>, 100 mm thickness and with approximately 3% binder content.

As a comparison a trial was made with two commercial polyacrylic resins. HF-05 and QRXF 1513 both from Rohm & Haas. Both resins were diluted with water and  
20 added 0.2% of a silane coupling agent.

The coupling agent was  $\gamma$ -aminopropyltriethoxysilane.

The mechanical strengths were measured according to EN1607 (delamination strength). The  
25 delamination strength was measured on both unaged and after exposure to high humidity and increased temperature in a climate chamber (70°C/95 RH; aged samples)

Results from the testing are shown in tables 4, 5 and 6 below.

Table 4

	Binder	Binder content	Oil content	Density Kg/m <sup>3</sup>	Delamination strength Unaged kPa	Delamination strength Aged (70°C/95% RH) kPa	Remaining strength
5	Binder according Example 8	3.1%	0.2%	98	9.7	4.0	41%
	Comparison example HF-05	3.3%	0.2%	101	7.2	1.3	18%
10	Comparison example QRXP	3.1%	0.2%	98	12.6	1.6	13%
15	Comparison example Standard phenolic resin	3.3%	0.2%	99	10.9	4.6	42%

Example 10

20

Table 5

Ex	Amine	Poly-acid	Water	Accele-rator	Base	Reaction conditions	Curing time 200°C	Curing time 250°C	Silane [%]
10	25.5kg DEA	17.6kg ADP	32.5 l	20% PAA	DEA	60°/130° for 3 hours	140 s	35 s	0.2

25

Table 6

Ex	Binder content [%]	Oil content [%]	Density [kg/m <sup>3</sup> ]	Delamination strength, unaged [kPa]	Delamination strength, aged (70°C/95%RH) [kPa]	Remaining strength [%]
10	3.5	0.2	140	10.1	3.3	36

5

Example 1110 Resin:

116 kg DEA was transferred to a 400 l reactor and heated to 60°C and stirred.

16.3 kg ADP was added and the mixture heated and reacted at 130°C for 60 minutes.

15 Thereafter cooled to 85°C and added (THPA) 33.8 kg. Thereafter 82.5 kg PTA was added and the temperature raised to 130°C and kept there for 120 minutes.

Thereafter the reaction mixture was cooled to 110°C and 100 kg water added.

20 The temperature stabilised at approx. 50°C. The mixture was stirred for further 15 minutes until homogenous.

The resin was cooled and transferred to a storage tank.

25 Resin solids content 62.2% determined at 200°C. Rest monomers 39% DEA of added, 12% THPA of added, 25% PTA of added. Average molweight about 600.

On a sample, a factory trial was carried out, whereby 4% DEA and 25% solids Acumer 1510 calculated on  
30 resin solids, 0.4% of sum solids silane and water to 25% solids content, was added and analysed.

Results of factory trial

Binder yield 60%

Delamination strength (EN 1607) 13.4 kPa (Terrænbatts

5 Industri) - Aged 3.6 kPa (70°C/95%RH)

Tensile strength 5.5 kPa (Flexi A Batts)

Example 12

10

Resin

24 kg DEA was transferred to a 80 l reactor and heated to 60°C and stirred.

6.7 kg ADP was added and the mixture heated and  
15 reacted at 130°C for 60 minutes.

Thereafter cooled to 85°C and added 6.9 kg  
/ THPA. Thereafter 16.9 kg PTA was added and the  
temperature raised to 130°C and kept there for 120  
minutes.

20 Thereafter the reaction mixture was cooled to  
110°C and 20.5 kg water added. The temperature stabilises  
at approx. 50°C.

The mixture was stirred for further 15 minutes  
until homogenous.

25 The resin was cooled and transferred to a  
storage tank.

Resin solids content 63.4% determined at 200°C.  
Rest monomers 37% DEA of added, 14% THPA of added, 25%  
PTA of added. Average molweight about 600.

30 On a sample, a factory trial was carried out,  
whereby 4% DEA and 25% solids Acumer 1510 calculated on  
resin solids, 0.4% of sum solids silane and water to 25%  
solids content, was added and analysed.

35 Results of factory trial

Binder yield 70%

Delamination strength (EN 1607) 12.1 kPa (Terrænbatts

Industri) - Aged 4.3 kPa (70°C/95%RH)

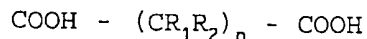
The invention is not limited to the above description, the requested rights are determined by the following claims.

## CLAIMS

1. Process for providing a binder for mineral wool products said process comprising the steps of:
  - mixing together under reactive conditions a carboxylic acid with an alkanolamine.
- 5 2. Process according to claim 1 wherein the carboxylic acid and the alkanolamine are firstly mixed together under reactive conditions to provide a resin, which resin is subsequently mixed with a separate carboxylic acid group containing polymer.
- 10 3. Process according to claim 2 wherein the carboxylic acid group containing polymer has a molecular weight lying in the ranges of 1000-300000, for example 1000-250000, preferably 1000-200000 most preferably having a molecular weights of around 60000, around 100000
- 15 and around 190000.
4. Process according to claims 2 or 3 wherein the carboxylic acid group containing polymer comprises a polyacrylic acid, polymethacrylic acid, polymaleic acid and/or co-polymers thereof.
- 20 5. Process according to claim 4 wherein the polyacrylic acid is selected from one or more of the following:
  - HF-05A, from Rohm & Haas,
  - Acusole 190, Rohm & Haas,
  - 25 - Acumer 1510, Rohm & Haas,
  - 41.600-2, from the Aldrich Chemical Company Inc.
6. Process according to any of the preceding claims wherein the carboxylic acid is a di, tri, or
- 30 tetra, carboxylic acid having a molecular weight of about 1000 or less, preferably about 500 or less, and most preferably about 200 or less.



7. Process according to claim 6 or 7 wherein the carboxylic acid is a di-carboxylic acid having the general formula:



5 wherein  $n \geq 2$  and preferably  $n \geq 4$ , and wherein  $\text{R}_1$  and  $\text{R}_2$  are independently selected from H or a lower alkyl group, preferably a methyl or ethyl group.

8. Process according to claim 6 or 7 wherein the carboxylic acid is selected from the group consisting  
10 essentially of: adipic acid, citric acid, trimellitic acid, sebacic acid, azelaic acid, and succinic acid and is most preferably adipic acid.

9. Process according to any of the preceding claims, wherein the alkanolamine is selected from the  
15 group comprising di, and tri-alkanolamines.

10. Process according to claim 9 wherein the alkanol amine is a secondary beta-hydroxy alkylamine, and most preferably an N-substituted alkanolamine.

11. Process according to claims 9 or 10,  
20 wherein the alkanolamine is selected from the group consisting essentially of, di-ethanolamine, 1-(m)ethyldiethanolamine, n-butyldiethanolamine, 3-amino-1,2-propanediol, 2-amino-1,3,-propanediol, tris(hydroxymethyl)aminomethane.

25 12. Process according to any of the preceding claims wherein the alkanolamine is diethanolamine.

13. Process according to any of the preceding claims, wherein the mole ratio of the carboxylic acid to the alkanolamine in the binder lies in the range of 0.1-  
30 1:1-0.1.

14. Process according to any of the preceding claims, wherein the weight percentage of the carboxylic acid group containing polymer in the binder lies in the range of 0.5-50, for example 10-40, preferably 15-30,  
35 most preferably about 20.

15. Process according to any of the preceding claims, wherein the alkanolamine is firstly heated to a first predetermined temperature whereafter the carboxylic

acid is added and the temperature of this mixture raised to a second predetermined temperature.

16. Process according to claim 15 wherein the first temperature is around 60°C and wherein the second temperature is at least about 90°C, and preferably lies in the range of about 95-200, for example about 120-150°C.

17. Process according to any of the preceding claims comprising the further step of adding one or more of the following to the binder:

- a coupling agent, for example an aminosilane, preferably gamma-aminopropyltriethoxysilane,
- a polymerisation accelerator, a curing accelerator and optionally further standard mineral wool binder additives.

18. Process according to any of the preceding claims wherein the reaction between the carboxylic acid and the alkanol amine is actively stopped, preferably by adding water to the resin reaction mixture, whereby water is preferably added by upto about 50% more preferably by more than 25% by weight of the resin mixture, preferably by weight of solids in the resin mixture.

19. Process according to claim 18, wherein a base is subsequently added to the reaction mixture.

20. Process according to claim 19 wherein the base is selected from the group comprising  $\text{NH}_3$ , diethanol amine (DEA), triethanolamine (TEA), optionally mixed with a polyacrylic acid, preferably Acumer 1510 Rohm and Haas, Mw. about 60,000.

21. Process according to claim 20 wherein weight % of base in the resin reaction mixture, preferably the weight % of the base calculated by weight of the solids in the reaction mixture, lies in the range of upto 20%, preferably upto 10%, more preferably 1-5% and most preferably 4% and wherein the base is preferably DEA.

22. Process according to any of the claims 19-21, wherein the weight % of the polyacrylic acid in the

mixture lies in the range upto 50%, for example 40%, preferably 30% and most preferably upto 25%.

23. Process according to any of the preceding claims further comprising the step of adding a silane, preferably in the range of 0.1%-5%, more preferably 0.2%-3% and most preferably about 1% by weight of the resin reaction mixture, preferably by weight of the resin solids, whereby the silane is most preferably prehydrolysed gamma-aminopropyltriethoxysilane (VS 10 142/Vitco).

24. Binder obtainable according to any of the preceding claims.

25. Binder for a mineral wool product comprising the reaction product of an alkanolamine, preferably as defined in any of the claims 9-12, and a carboxylic acid, preferably as defined in any of the claims 6-8.

26. Binder according to claim 25 further comprising a carboxylic acid group containing polymer as 20 defined in any of the claims 2-5.

27. Binder according to any of the claims 24-26 having a curing time of at most 100, for example 90, preferably at most about 50, for example at most about 45 seconds at 250°C, most preferably 35 seconds at 250°C, 25 for example 200°C.

28. Binder according to any of the claims 24-27 having a curing time of at most 100, for example 90, preferably at most about 50, for example at most about 35 seconds at 200°C.

30 29. Binder according to any of the claims 25-28 further comprising a silane as defined in claim 23.

30. Process for providing a mineral wool product comprising the steps of contacting mineral fibres with a binder according to any of the preceding claims 35 24-29, followed by a curing step.

31. Mineral wool product obtainable according to claim 29.

32. Mineral wool product comprising a binder according to any of the claims 24-29.

33. Mineral wool product comprising a binder according to any of the claims 24-29, which mineral  
5 product has been cured at a temperature of at least 100, for example at least 150, preferably at least 200°C.

34. A mineral wool binder having an aged strength measured according to the Grit bar test of at least 0.5, preferably at least 1,0, more preferably at  
10 least 1,5 and even more preferably at least 2,0 and most preferably at least 2,5 N/mm<sup>2</sup>.

35. Mineral wool binder according to claim 34 having a remaining strength measured according to the Grit bar test of at least 10, for example at least 20,  
15 preferably at least 30, for example at least 40, most preferably at least 50%.

36. Use of a reaction mixture of an alkanolamine and a carboxylic acid, optionally mixed with a carboxylic acid group containing polymer, as a binder  
20 for a mineral wool product.